Derivations and Constraints in Phonology

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Phonological Derivations and Historical Changes in Hebrew Spirantization

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1. INTRODUCTION

Chomsky (1995: 224) cites Hebrew spirantization as an example of a phonological phenomenon whose conditioning factors are rendered opaque (even absent) by the operation of later processes in the phonological derivation in standard rule-based generative phonology Because Optimality Theory (OT, Prince and Smolensky 1993) is built on surface output conditions (and in later versions input–output and output–output correspondence constraints), any such cases of intermediate representations are non-trivial questions to be addressed.

Idsardi (forthcoming) examines some aspects of the synchronic grammar of Tiberian Hebrew which interact with spirantization, and concludes that no non-derivational version of OT can handle all of the facts of Tiberian Hebrew spirantization. The present chapter extends these findings by examining the historical development of Hebrew, concentrating on changes that interact with spirantization. Idsardi (forthcoming) considers several possible OT grammars of Tiberian Hebrew, using various versions of Optimality Theory. The present paper considers only the account in McCarthy (forthcoming), and the generative account offered in Idsardi (forthcoming).

2. TIBERIAN HEBREW SPIRANTIZATION

2.1 Basic facts

Non-emphatic stops alternate with fricatives in Tiberian Hebrew (TH), the language of the Bible as annotated by the Masoretes. Alternations such as (1) (adapted from McCarthy 1979) are typical.

(1) a [t ~ ð, k ~ x] kāḥāy ‘white 3ms perf’ (Josh 8: 32)
jīxādā ‘white 3ms impf’ (Isa 44: 5)

b [g ~ ɣ, d ~ ð] gaːðálu ‘be great 3p perf’ (Jer 5: 27)
jirḍá ‘lu: be great 3mp impf’ (Ruth 1: 13)
Modern Hebrew (MH) retains only the \([p \sim t], [b \sim v],\) and \([k \sim x]\) alternations, having lost the alternations \([t \sim \theta], [g \sim \gamma],\) and \([d \sim \delta]\). This is discussed in more detail below. The basic generalization in TH is that fricatives appear postvocically and stops appear elsewhere (postconsonantally and at the beginning of words following pause), but this has several complications, which are discussed briefly below, and in more detail in Idsardi (forthcoming.)

TH had the consonant system in (2). following Prince (1975: 8–9) Stop–spirant pairs in the obstruent series are paired vertically

\[
\begin{align*}
\text{Obstruents} & \quad \text{Sonorants} \\
\text{a} & \quad \text{b} & \quad \text{p} & \quad \text{t} & \quad \text{d} & \quad \text{s} & \quad \text{z} & \quad (\text{s}) & \quad \text{f} & \quad \text{v} & \quad \theta & \quad \delta \\
\text{b} & \quad \text{f} & \quad \nu & \quad \emptyset & \quad \emptyset & \quad x & \quad \emptyset & \quad \gamma & \quad \text{m} & \quad \text{n} & \quad \text{l} & \quad \text{r} & \quad \text{j} & \quad \text{w} & \quad \text{h} & \quad \text{i} & \quad \text{h} & \quad ?
\end{align*}
\]

The consonants in (2a) are both phonemic and phonetic; the consonants in (2b) are only phonetic.

Although spirants usually appear following a surface vowel, there are a number of complications to this generalization. The range of environments in which spirants appear in TH is given in (3) \(^1\) (see Idsardi forthcoming for further examples and discussion).

(3) Spirants occur:
\(\quad\) a. after vowels present at both UR and SR (as in (1), above)
\(\quad\) b. after vowels present at UR but not at SR (deleted vowels):
\(\quad\) \(/\text{katab} + \text{u/} \rightarrow [\text{ka}:\text{θ}u:]\) ‘write 3\text{PERF}’ (Ezra 4: 6)
\(\quad\) compare \(/\text{katab/} \rightarrow [\text{ka}:\text{θ}a:v]\) ‘write 3\text{MS PERF}’ (Josh 8: 32)
\(\quad\) c. after vowels present at SR but not at UR (epenthetic vowels):
\(\quad\) \(/\text{malk}/ \rightarrow [\text{mêlex}]\) ‘king’ (Gen 14: 1)
\(\quad\) d. between words in the same phrase:
\(\quad\) \([\text{wayya}:\text{θ}a:\text{l}u: \text{ve}:\text{θ}:\text{e}:\text{l}]\) ‘and go up 3\text{MP IMPF} Bethel’ (Judg 20: 18)
\(\quad\) e. after a vowel when an intervening syllable-final laryngeal is deleted
\(\quad\) \([\text{ma}:\text{θ}a:\text{i}(\text{?})\text{θ}:i:]\) ‘find 1\text{S PERF}’ (1 Kgs 21: 20)
\(\quad\) f. across the glides \(/\text{j}, \text{w}/:
\(\quad\) \([\text{ha}:\text{θ}a:]\) ‘live 3\text{S PERF}’ (Gen 12: 13)
\(\quad\) g. with degeminated consonants:
\(\quad\) \(/\text{rabb}/ \rightarrow [\text{ra}:v]\) great much ms’ (Gen 24: 25)
\(\quad\) compare \(/\text{rabb-im}/ \rightarrow [\text{ra}:\text{bb}:m]\) ‘many mp’ (Num 20: 11)
\(\quad\) h. to both onsets and codas \([\text{ka}:\text{θ}a:v]‘write 3\text{MS PERF}’ (Josh. 8: 32)

It is particularly important to notice that the occurrence of spirants is not predictable from the surface syllabic position of the consonant. Spirants occur both as codas and as onsets. The conditioning factor is rather the adjacency to a preceding nucleus (Schein and Steriade 1986), not to the syllabic affiliation of the segment in question.

However, even with the occurrence of spirants in all the positions catalogued

\(^1\) Underlining is used to draw attention to the place of interest in the form not to indicate spirantized variants.
in (3) spirant members of stop–spirant pairs are banned from other environments, catalogued in (4)

(4) Spirant realizations of stop–spirant pairs do not occur:
   a postpausally
   b after consonants (except (3b) and (3f) cases)
   c with surface geminates (cf. (3g)):
      underlying /rabb-im/ → [rabbː:m] ‘many mp’ (Num. 20: 11)
      derived /ja-n-kateb/ → [jikkaθeːv] ‘write 3MS IMPF Nifʕal’ (Esther 8: 5)
   d across gutturals (cf. (3f))
      [jahbːːt] ‘strike 3MS IMPF’ (Isa. 27: 12)
   e when ‘metathesized’ into postconsonantal position:
      [ləšhitabbət] ‘praise perf Hitpaʕel’ (Ps. 106: 47)
      cl. [wəšhitbətːrəx] ‘and bless 3MS PERF Hitpaʕel’ (Deut. 29: 18)
   f after a deleted vowel following a prefix (cf. (3b)):
      /ja-katab/ → [jixtəv] ‘write 3MS IMPF’ (Isa. 44: 5)
      /na-katab/ → [nixtəv] ‘write 3MS PERF Nifʕal’ (Esther 8: 8)
   compare /katab-ú/ → [kaθuːv] ‘write 3P PERF’ (Ezra 4: 6) where the deleted vowel is later in the stem
   and /bəkətəb/ → [bixtəv] ‘when writing’ (Ps. 83: 6) where the deleted vowel follows a proclitic
   g following a word ending in a glide (cf. (3d,f)):
      [wajəsaw dəwiːd] ‘and order 3MS juss David’ (1 Chr. 22: 17)

There are also other spirants which do not alternate with stops (e.g. [s f]). These fricatives can occur in all the relevant phonetic environments listed above.

The crucial test cases for any theory of spirantization is the difference in behaviors between (3b) and (4f), for together they show that spirantization does not uniformly occur following all deleted vowels. Because these cases are so crucial, it will be necessary to briefly review the morphology of the verb stem in Hebrew.

The perfect, imperfective and intensive perfect (Pišel) forms for the verb root /ktb/ ‘write’ are shown in (5). Sound triliteral verb stems can show four different surface shapes: CVCCVC, CVCCVC, CVCC, and CCVC. Vowel length is phonologically predictable, and there are different agreement markers for the Perfect and Imperfect aspects
McCarthy (1979) represents a watershed in the analysis of stem-shape patterning in Semitic morphology. Previous accounts, such as Prince (1975), had built stem shapes from an underlying CVCVC form through morphophonological rules of deletion and insertion. McCarthy suggested instead that the stem shape was supplied morphologically for the particular binyan and aspectual class, with the root consonants then associating to the template. In the case of the CVCC stems, however, McCarthy (1979) also derived this stem shape from /CVCCVC/ with a phonological rule of vowel deletion. More recently, McCarthy and Prince (1990), McCarthy (1993), and Dobrin (1993) have argued for a return to the idea that all verb stem shapes are based on a CVCVC stem. They argue that the stem shapes CCVC, CVCC, and CVCCVC must be derived through morphophonological processes because these shapes do not define valid prosodic constituents and are therefore incoherent from the standpoint of Prosodic Morphology. For example, the first C in the CCVC case is syllabified not with the stem but with the preceding prefix. Therefore the prosody of a stem exhibiting this shape is a mora plus a syllable, [ι ι], which is not a valid prosodic constituent. The shape CVCCVC is also incoherent, they argue, because it is not a valid foot type, being too large to be either a trochee or an iamb. McCarthy and Prince derive the CVCCVC shape by infixing a prosodic position (a mora) after the first syllable of the CVCVC stem. The CCVC case is handled in Arabic by a phonological rule of vowel deletion (McCarthy 1993: 202). Rappaport (1985) likewise argues that the Hebrew imperfective CCVC shape arises from a phonological process of vowel deletion. In order to generate the correct surface forms (including spirantization) in the Hebrew case, however, prefixed stems must undergo two levels of calculation, both cyclic and noncyclic; see Rappaport (1985) for details. The existence of the cyclic level is crucial in capturing the difference in spirantization of consonants following deleted vowels; compare [jix_to:v'] ‘write 3MS IMPF’ with [ka:θ_vu:] ‘write 3MS PERF.’ No spirantization occurs with the /t/ following the deleted vowel in the imperfective, but the spirant [v'] does occur following the deleted vowel in the perfective. Any analysis of spirantization must capture this distinction. In Rappaport’s derivational analysis (carried over into this chapter) this is accounted for by deleting the vowel in the imperfective in the cyclic stratum, while deleting the vowel in the perfective noncyclically; see the next section for details.

2.2 A rule-based analysis

Idsardi (forthcoming) accounts for the behavior of spirantization in Tiberian Hebrew with the rules in (6) and (7). Of course there are other morphological and phonological rules in Tiberian Hebrew, see especially Prince (1975), Dresher (1983), Rappaport (1985), and Malone (1993) for examples and analyses. The summary of rules in (6) and (7) is limited to those rules that interact relatively directly with spirantization. The morphological component
Hebrew Spirantization

is responsible for constructing the underlying representations for the phonological component. In the case of Tiberian Hebrew, the rules relevant for spirantization are the limited infixation of /h/ in the Hitpaʕel (commonly analysed as metathesis), and the construction of stem forms by infixation (medial gemenation) and vowel deletion (the CCVC stem shape characteristic of the imperfect tenses). Assuming that syllable structure is encoded in the basic template form (and thus available in the morphology) the rules are then as in (6).

(6) a. Medial gemenation \( \emptyset \rightarrow x / [\text{[pFtel, etc} \ [\text{CV}] \ [\text{-} \text{-}] \text{]} \)

b. Hitpaʕel formation
   i. \( \emptyset \rightarrow x / [\text{Hitpaʕel} \ x \ [\text{-} \text{-}] \text{]} \)
   \( \text{[\text{-} \text{son}] \ [\text{-} \text{son}] \text{Coronal} \text{]} \)
   ii. \( \emptyset \rightarrow h / [\text{Hitpaʕel} \ [\text{-} \text{-}] \text{]} \)

If the Hitpaʕel infixation, (6bi), applies, then all Guttural features spread rightward from the stem-initial consonant. The consequence of this is that the infix will agree in voicing and [RTR] (emphasis) with the stem-initial segment. As noted by Gesenius (1910: 149), some stems beginning with /hi/, /ki/ or /ti/ exceptionally form their Hitpaʕel forms through infixation. The infixation is also general in other Semitic languages. The analysis of the Hitpaʕel formation as infixation solves a problem with voicing assimilation in Modern Hebrew, see below.

The phonological rules are given in their application order in (7). Each rule is specified for whether it applies cyclically, noncyclically, or in both strata. Explication and justification for the formulations of the rules can be found in Idsardi (forthcoming).

(7) a. Gemination (noncyclic) \( x \ x \)

   i. Root \( \text{[\text{-} \text{-}] \text{]} \)

   Oral

b. Pre-tonic Lengthening (noncyclic) \( \emptyset \rightarrow x / [\text{(*) (*)} \text{]} \)

c. Laryngeal Deletion (noncyclic) \( x \ [\text{-} \text{-}] \text{]} \)

d. Compensatory Lengthening (noncyclic) \( x \ x \)

e. Vowel Reduction (cyclic and noncyclic) \( * \rightarrow \emptyset / [\text{-} \text{-}] \text{]} \)

f. Word-Final Degemination (noncyclic) \( x \rightarrow \emptyset / [\text{-} \text{-}] \text{]} \ \

\( \text{[\text{-} \text{-}] \text{]} \text{]} \)

g. Spirantization (noncyclic) \([\text{-} \text{son}] \rightarrow [\text{+ cont}] / [\text{-} \text{-}] \text{]} \)

Nucleus
h. Schwa Deletion (cyclic and noncyclic)  \[ \varepsilon \rightarrow \emptyset / V_\sigma [C \ldots \sigma] \]
\[ \text{Oral} \]

i. Closed syllable i (cyclic and noncyclic)  \[ V \rightarrow \text{i/} / \ldots C \sigma] \]
\[ \text{Oral} \]

j. n Deletion (cyclic)  \[ \chi \quad \text{C} \]
\[ \chi \quad \text{i} \quad \text{n} \quad \text{Oral} \]

Idsardi (forthcoming) argues that, because the stop/spirant distinction was not contrastive in TH, the 'stops' in (2) were underlyingly without any value for the [cont] feature. Spirantization (7g) provides these items with [t contour], and a general rule supplies the [- cont] default otherwise, with these rules disjunctively ordered by Kiparsky’s (1973) Elsewhere Condition (cf. Chomsky’s 1951 MR34).

As discussed above, the appearance of the shortened stem shapes CCVC and CVCC is governed by the operation of the rules of Vowel Reduction and Schwa Deletion on the base stem shape CVCVC. Derivations of forms exhibiting this operation are shown in (8). Verb forms containing prefixes (Nif’al, Imperfectives, etc.) are subject to the cyclic block of rules; forms without prefixes do not undergo a cyclic calculation. Imperatives and infinitive absolute forms, which appear not to have a prefix, are analyzed here as having a \( \emptyset \)- (zero) prefix, and are therefore subject to the cyclic rules.

(8) Morphology

<table>
<thead>
<tr>
<th>Cyclic Reduction</th>
<th>[(ja-katob_cyc_u_non)]</th>
<th>[katab_u_non]</th>
<th>[b#(\emptyset-katob_cyc_non)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>jakatob</td>
<td>n/a</td>
<td>katob</td>
<td>(x)</td>
</tr>
<tr>
<td>x</td>
<td></td>
<td>(ka)(to)b</td>
<td></td>
</tr>
<tr>
<td>(ja)(ka)(to)b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td></td>
<td>(jik)(to)b</td>
<td></td>
</tr>
<tr>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed σ i</td>
<td>(jik)(to)b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noncyclic Lengthening</td>
<td>(jik)(to)(bu)</td>
<td>x ( x x)</td>
<td>(x)</td>
</tr>
<tr>
<td>Reduction</td>
<td></td>
<td>(ka)(ta)(bu)</td>
<td>(b#)(ka)(to)b</td>
</tr>
<tr>
<td>x</td>
<td></td>
<td>(ka):(ta)(bu)</td>
<td></td>
</tr>
<tr>
<td>(jik)(to)(bu)</td>
<td></td>
<td>(ka):(ta)(bu)</td>
<td></td>
</tr>
<tr>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirantization</td>
<td>(jik)(ta)(bu)</td>
<td>x ( x x)</td>
<td>(x)</td>
</tr>
<tr>
<td>Reduction</td>
<td></td>
<td>(ka):(theta)(vu)</td>
<td>(b#)(xa)(theta)v</td>
</tr>
<tr>
<td>x</td>
<td></td>
<td>(ka):(theta)(vu)</td>
<td></td>
</tr>
<tr>
<td>(jix)(ta)(vu)</td>
<td></td>
<td>(ka):(theta)(vu)</td>
<td>(b#)(theta)v</td>
</tr>
<tr>
<td>x</td>
<td></td>
<td></td>
<td>(b#)(theta)v</td>
</tr>
<tr>
<td>Closed σ i</td>
<td>(jix)(ta)(vu)</td>
<td>x ( x x)</td>
<td>(x)</td>
</tr>
<tr>
<td>Other rules:</td>
<td>[jih_ev_d_cyc_non]</td>
<td>[ka_theta_v_d_cyc_non]</td>
<td>[b#(\emptyset-katob_cyc_non)]</td>
</tr>
</tbody>
</table>
As discussed in Idsardi (forthcoming), the proclitic of infinitive construct form /l#katob/ → [lixtos] is lexically specified as [+ cyclic]. Therefore, the derivation of this form is parallel to the imperfective forms in the relevant respects.

2.3 An Optimality Theoretic analysis

The most important change from generative models of phonology to Optimality Theory is the total elimination of phonological rules. Instead of rules, surface well-formedness constraints rank output candidates in terms of how well they meet surface-orientated conditions. Thus, in principle all constraints are violable, and the grammar of a language is an ordering of the universal constraints from most to least important. The general form of the theory is ‘generate and test’, as in (9).

\[ \text{Gen(input)} = \{ \text{candidates} \} \]
\[ \text{Eval(\{ \text{candidates} \}, \{ \text{constraints} \})} = \text{output} \]

We will not construct a substantial partial OT grammar for Hebrew here, but will assume that constraints can be formulated and ranked to generate the surface patterns for processes other than spirantization. The surface orientation of OT constraints allows us to be somewhat agnostic about how the rest of the constraints are formulated and ranked, since the constraints should be in terms of surface properties, or input–output relations.

McCarthy (forthcoming) offers a novel approach to the problem of accounting for phonological opacity within a non-derivational version of OT. Because of the importance of the concept of opacity in the rest of the discussion, I give the definition of opacity in Kiparsky (1976: 178–9) in (10).

\[ \text{(10) [A] process P of the form} \]
\[ A \rightarrow B / C \_ D \]
\[ \text{[is] opaque to the extent that there are phonetic forms in the language having either (i) or (ii):} \]
\[ \text{(i) A in the environment C \_ D} \]
\[ \text{(iia) B derived by the process P in the environment ‘other than C \_ D’} \]
\[ \text{(iib) B not derived by the process P (i.e underlying or derived by another process) in the environment C \_ D} \]

Hebrew spirantization is a typical example of an opaque rule, because later rules, such as vowel deletion, obscure the application environment in the surface form. The ordering of spirantization before deletion is an opacity of type (10iiia), because at the surface a spirant appears postconsonantally.

McCarthy proposes that OT constraints be parameterized for certain aspects of their evaluation. His formulation of the Tiberian Hebrew spirantization constraint is given in (11).
(11) No-V-Stop Tiberian Hebrew Version (with opacity . . . )

* Condition Level
\[\begin{align*}
\alpha & \quad V & \quad \text{Indifferent} \\
\beta & \quad [-\text{son, } -\text{cont}] & \quad \text{Surface} \\
\text{Linear Order} & \quad \alpha > \beta & \quad \text{Indifferent} \\
\text{Adjacency} & \quad \text{Strict} & \quad \text{Indifferent}
\end{align*}\]

McCarthy explains that ‘in correspondence terms, the meaning of this constraint is this: the constraint is violated if a surface stop \(\beta\) or its underlying correspondent is immediately preceded by a vowel’. By parameterizing the constraint in this way, spirantization is predicted following surface vowels (epenthetic or underlying) and if a consonant was preceded by a vowel in the underlying representation.

As discussed in Ildsardi (forthcoming), the claim that all underlying V-Stop sequences show surface spirantization of the stop is false. In particular, imperfective verb forms do not show spirantization of the second root consonant even though it is underlyingly preceded by a vowel (as argued in e.g. McCarthy 1993, discussed above), for example TH [jixbað], MH [jixbad] ‘he will be heavy’. Therefore McCarthy’s account does not correctly differentiate between the two behaviors following deleted vowels illustrated by the contrast between (3b) and (4f), a distinction which persists in MH. However, I shall not be primarily concerned with this problem in the following discussion. Instead, I seek to test the claim that the absence of opacity is less marked, and that languages will change diachronically so as to become less marked, and therefore less opaque.

3. MODERN HEBREW PHONOLOGY

3.1 Basic facts

Hebrew has undergone many changes since the Biblical period. Some of these changes are of interest with regard to the proper analysis of spirantization. Here I will consider only the standard Israeli Hebrew dialect, as described for example in Rosén (1962; 1977), Bolozky (1978; 1980), Berman (1978), and Baltsan (1992). I will not consider Sephardic or Ashkenazic dialects, where they differ from the descriptions below. The history of the development of Hebrew is complex, and is full of uncertainties. The widespread use of unpointed scripts throughout the history further complicates the always difficult problem of interpreting orthographic conventions. With all these caveats, a summary of the changes from TH to MH given in Bolozky (1978: 11–13) is given in (12).
Mergers and phonemic restructuring

[Of] the original set of six spirant alternants... only the two labials /b/ and /p/ and the voiceless velar /k/ have spirant counterparts — [v], [f], and [x], respectively.

The voiceless pharyngeal fricative /h/ [=h] is typically pronounced exactly like its velar counterpart [x].

[T]he glide /w/ is generally pronounced exactly like the labial spirant [v].

[T]he so-called ‘emphatic’ consonants /ʃ/, /ɬ/, and /q/ no longer occur in any native Hebrew speech...[and] are today pronounced as the dental affricate [ts], the dental stop [t], and the velar stop [k], respectively.

Degemination

Another loss in the consonantal system is the nonrealization of consonantal gemination.

guttural deletion

[T]he voiced pharyngeal fricative /ʕ/ ‘ayin has coalesced with the glottal stop /ʔ/ aleph and is most generally deleted, just as are original glottal stops.

With the addition of the phoneme /ʕ/ through borrowings such as [fibrek] ‘fabricate’, [falafal] ‘falafal’ (Zilkha 1989), and [finteż] ‘he fantasized’, [festival] ‘festival’ (Ravid 1995: 82), Modern Hebrew has the underlying consonant system shown in (13).

Obstruents    Sonorants
p b t d s z ʃ s k g m n l r j ɦ h
f v x

See below for the lack of spirantization with /k/ < TH /q/, and justification for the inclusion of /ʕ?/ in the underlying inventory.

It is particularly fascinating that so much of the relevant data regarding spirantization remains much the same in Modern Hebrew. For example, the contrast between infinitive constructs in /l#l/ and /b#l/ which motivated Prince’s (1975) cyclic analysis continues, as observed by Berman (1978: 288) Some examples from MH are given in (14).

(14) a. [lispor] ‘to count’ [bisfor] ‘on counting’
    b. [lijpox] ‘to pour’ [bijfox] ‘on pouring’
    c. [limkor] ‘to sell’ [bimxor] ‘on selling’

As Ldsardi (forthcoming) shows, this data cannot be handled in any nonderivational version of OT. The continuation of this pattern of data for thousands of years indicates that this is a robust fact of the language, and must be handled in any theory of phonology. However, in this chapter I will concentrate on some of the things that have changed in the grammar of Hebrew that interact with spirantization and evaluate whether they have decreased opacity in the grammar or not.
3.2 Implications for the analyses

In the following sections I will examine the diachronic implications for the two analyses of Tiberian Hebrew. What must be changed in the grammars of the two analyses from TH to MH?

The two theories predict rather different things. The rule-based theory predicts rule change (in parameters for target/environment/level/conditions; see Archangeli and Pulleyblank 1995), rule loss, and rule addition, especially to the end of the grammar, as explained by Halle and Kiparsky:

(15) the new rules are ordinarily added at the end of the grammar . . . (Halle 1962: 68)

the vast majority of sound changes are rules added to the end of the existing sequence of phonological rules . . . (Kiparsky 1970: 309)

Rule addition at the end of the grammar is the most important type of change for the purposes of the present chapter. Rules added at the end of the grammar do whatever they do. They may be in feeding, bleeding, counterfeeding, or counterbleeding relationships with rules earlier in the grammar. This theory predicts it should be possible, even normal, for languages to show an increase in the opacity of the grammar through rule addition. Of course, if the system becomes so opaque that it cannot be readily learned, it will then be restructured.

The OT perspective is diametrically opposed, as is shown by the quotes from McCarthy (forthcoming).

(16) Kiparsky’s concern is with understanding how minimization of opacity drives diachronic change (p. 1)

Accepting Kiparsky’s dictum that phonological opacity is marked, I will stipulate that the default form of a phonological constraint—the form in which it is represented in UG—has all of its level specifications set to ‘surface’. A constraint of this type is a true output target. . . . It is not opaque, since the conditions of obedience or violation can be read off of surface structure in a completely transparent way (p. 6)

It is clear that, in contrast to the rule approach which has no direct measure of opacity, there is explicit representation of opacity in the OT constraint parameters, and the default state for these parameters is for true surface (transparent) evaluation. Therefore, with OT we would not expect increases in grammar opacity to be favored occurrences in language change.

The rest of this section will examine the changes in the historical development of Hebrew relating to spirantization, focusing on what changes in the grammars would account for these changes, and whether or not these changes

• increased the opacity of the grammar.
3.2.1 Phonemic restructuring

The most notable change in Hebrew spirantization has already been mentioned—the restriction of the set of spirantizable stops. The problem this presents is succinctly explained by Bolozky (1978: 33):

(17) Spirantization no longer applies to all six members of the three pairs of non-back stops, but is confined to the alternations of *p, b, and k with the fricative *f, v, and x, respectively. Note that these three sets of stop–spirant alternations cannot be associated with any accepted ‘natural’ phonological class of segments.

It is possible to exclude the coronals by restricting spirantization to Peripheral stops (Rice 1994; this restriction is attested in Samaritan Hebrew; see Murtonen 1990), but this still leaves MH */g/ → [γ] to be explained.²

I believe that an illuminating answer arises from examining the set of outputs of the spirantization process in Modern Hebrew, [f v x]. In Biblical Hebrew these sounds were only phonetic variants of the spirantizing stops, but this is not the case in Modern Hebrew. Owing to historical mergers (TH /wl > MH /vl and TH /hl > MH /x/), MH acquired new phonemes /v x/. Due to borrowings MH has also acquired the phoneme /l/. It has not, however, acquired a phoneme /γ/, although [γ] is a phonetic variant of /k/ and /x/ through voicing assimilation (see below). Therefore, if we restrict the operation of spirantization to produce only phonemes as outputs, we can uniquely identify the set of stops undergoing the rule. But this is simply the Structure Preservation condition of Lexical Phonology (Kiparsky 1982). Of course, the addition of new phonemes has also meant that there are now instances of spirants in positions where they could have been created by the spirantization rule (e.g. following surface vowels, [patax] ‘he opened’ <TH /patah/, introducing opacity of type (10iib) into the language.

Elan Dresher (pers. comm.) has suggested a slight variation on this story (see also Faber 1986; Katz 1993). Since for many centuries Hebrew was primarily a liturgical language, spirantization might have been restricted to producing phonemes in the first language of the speakers. Interestingly, the major European first languages of relevant interest (German, Russian, Polish) all have phonemic /f v x/ and lack phonemic /γ/. Thus, we might have two slightly different stories regarding the development of the structure-preserving restriction. The first says that under the influence of languages with /f v x/ Hebrew innovates /f v x/. Then spirantization changes to be structure-preserving. The second story would allow the speakers’ first-language phoneme set including /f v x/ to restrict the operation of spirantization directly, without first ‘importing’ the phonemes into Hebrew. This is a very subtle and clever distinction, and may shed light on other inter-language phenomena, but cannot be resolved for the present case.

² Asterisks(*) are only used to mark ungrammatical forms, not to indicate historical sources.
Work in Lexical Phonology (Kaisse 1990; Rice 1990; Hyman 1993; Iverson 1993) has demonstrated that noncyclic rules can be structure-preserving, and Kiparsky (1993) shows that rules must be individually marked as to whether they are subject to the Derived Environment Condition. Thus the fact that a rule obeys Structure Preservation is not an infallible indication that the rule is cyclic. So let us leave the spirantization rule in the noncyclic stratum, but mark the rule as Structure-Preserving, and thereby preclude /g/ from being spirantized to [γ]. It seems premature at this point to speculate whether the structure-preserving restriction then directly prevented /t d/ → [θ ð] (or forced /t d/ → /s z/) see Faber 1986) or whether spirantization was separately restricted to Peripheral segments.

Employing output conditions like Structure Preservation would seem to play directly to OT's strengths. But it is extremely important to realize that it is only the output of the spirantization process itself that has been made structure-preserving. In particular it is incorrect to view Structure Preservation as a constraint on surface outputs in MH. This can be very clearly seen by examining the interaction of spirantization with regressive Voicing Assimilation (Bolozky 1978: 16). Bolozky notes two idiosyncrasies of the rule in careful speech: /l/ does not induce voicing on a preceding segment (a phenomenon shared with Russian) and /x/ does not become [γ]. Bolozky notes that in fast speech these restrictions can be lifted. As regards /x/ → [γ], we can account for the careful speech restriction by saying that Voicing Assimilation is subject to Structure Preservation in careful speech, but that the Structure Preservation restriction on voicing assimilation is lifted in fast speech. Bolozky gives the examples in (18) (see also Kisseberth 1977: 51–2).

(18) Careful speech    Fast speech
[exzir]       [ezzir]     'returned tr'    /hzzr/    /hzzr/
[jixbo]       [jiybo]     'he will conquer' /kbs/    /kbs/

Thus in fast speech it is possible for /k/ → /x/ → [γ]. Notice that the output does not meet Structure Preservation, for there is no phoneme */̖//. But, the spirantization process by itself is structure-preserving. Now consider a minimally different case, that of /g/ between a vowel and a voiceless obstruent, as in (19).

(19) /ja-gasos/ → [jikos] */jixos* 'he will agonize/be about to die'
    /ja-gaxon/ → [jikoxn] */jixon* 'he will lean'

It is impossible to chains to together spirantization and Voicing Assimilation so as to produce */g/ → */̖/ → /x/, even though the output segment would be structure preserving because /x/ is a phoneme. Thus it is not the overall Input–Output relation that is relevant for Structure Preservation, but only the operation of the spirantization process. Since /g/ → [γ] is not structure-preserving, the process of spirantization is blocked, and therefore when Voicing
Assimilation applies /g/ → [k]. Note also that the existence of forms such as [jiksos] is an opacity of type (10i).

In contrast, an examination of the surface forms in terms of Structure Preservation in OT makes the wrong predictions, as shown in (20).

<table>
<thead>
<tr>
<th>(20) /ja-gasos/</th>
<th>Voicing Assimilation</th>
<th>Structure-Preserving</th>
<th>Spirantization</th>
</tr>
</thead>
<tbody>
<tr>
<td>a  jiksos</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>b  jixsos</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>c  jiyysos</td>
<td>✓!</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>d  jigsos</td>
<td>✓!</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Since the output [x] is an element of the phonemic inventory, the candidates (20a) and (20b) tie for the purposes of Structure Preservation. Therefore *[jixsos] should be the preferred candidate because it also satisfies the spirantization constraint, an unwanted Emergence of the Unmarked effect. Thus, it is clear that an explanation in terms of Structure Preservation as an OT output constraint fails. The proper results fall out directly if Structure Preservation is applied as a constraint on the application of individual rules. The correct results do not follow if Structure Preservation is calculated over entire derivations.

Thus, OT cannot use a general constraint for Structure Preservation, but must break Structure Preservation into several separate constraints. One of these could be an Ident constraint freezing the relevant partial segment structure which identifies /g/, as in (21).

(21) Root
     / \ |
    | [− cont] Place Laryngeal
    | |
    \ Dors [ + voice ]

But this is not the end of the matter. We must properly rank the constraints so as to allow /g/ → [k] but not /g/ → [γ] or /g/ → [x]. That is, [−cont] is more frozen than [ + voice]. The relevant ranking would obviously have to be Voicing Assimilation (VA) >> (21) >> (11). However, if (21) is evaluated as a binary constraint, this still yields the wrong results, through the same unwanted Emergence of the Unmarked effect, as shown in (22).

<table>
<thead>
<tr>
<th>(22) /ja-gasos/</th>
<th>VA</th>
<th>(21)</th>
<th>(11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a  jiksos</td>
<td>✓</td>
<td>{ [− voice] }</td>
<td>✓</td>
</tr>
<tr>
<td>b  jixsos</td>
<td>✓</td>
<td>{ [− voice], [ + cont] }</td>
<td>✓</td>
</tr>
<tr>
<td>c  jiyysos</td>
<td>✓</td>
<td>{ [− voice], [ + cont], [Lab] }</td>
<td>✓</td>
</tr>
<tr>
<td>d  jigsos</td>
<td>✓!</td>
<td>{ [+ cont] }</td>
<td>✓</td>
</tr>
<tr>
<td>e  jigsos</td>
<td>✓!</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

If (21) is evaluated as a binary constraint, then (22a–c) all meet the voicing assimilation requirement and tie on (21) as well (all of them violating it).
Evaluation would then fall to the relative performance on the spirantization constraint, which (22b,c) meet and (22a) fails. Since (22b) is more faithful to the input in terms of retaining the Dorsal articulation (Max-Dorsal), (22b) would be the winning candidate. Since (22a) is the correct output, (21) must be evaluated as a gradient constraint, or be exploded into some kind of contextual Ident constraints, such as Ident ([-cont]) for /g/, perhaps through a parameterized constraint like (23).

(23) * \[ \begin{array}{c|c|c} \text{Condition} & \text{Level} \\ \hline \alpha & g & \text{Indifferent} \\ \beta & [+ \text{cont}] & \text{Surface} \\ \text{Relation} & \beta \in \alpha & \text{Indifferent} \end{array} \]

This constraint means that no instance of a [+ cont] feature should be contained in a surface segment [g], or in a surface segment whose input correspondent is /g/. Constraint (23) is effectively a kind of anti-corresponcence constraint barring /g/ from surfacing as any kind of continuant \([\gamma \times z \times s \ldots]\) (see Archangeli and Suzuki, Chapter 6 above, for similar discussion [Editor]). The problem here with both (21) and (23) is that they both simply stipulate that underlying /g/ cannot change its value for [− cont]. That is, they are simply brute force formal ways of excluding /g/ from spirantization. In contrast, the rule-based Structure Preservation account explains the behavior of /g/ in terms of an independently necessary phonological structure—the phoneme inventory. But because the relevant evaluation of the adherence to Structure Preservation is the output of the spirantization rule (an intermediate level), it is impossible to use Structure Preservation evaluated over surface forms, as OT would require, and therefore constraints specific to /g/ must instead be formulated.

One minor clarification regarding voicing assimilation should be made at this point. As Bolozky (1978: 22) shows, the Hiptafel 'metathesis' interacts with voicing assimilation so that application to /ž/-initial stems yields [-zd-] rather than [-st-], as the surface output, as in (24).

(24) /hit-zaken/ [hizdaken] ‘grow old’
    /hit-zarez/ [hizdarez] ‘hurried’
    /hit-zakets/ [hizdakets] ‘stood up’

As Bolozky points out, one possible conclusion from such data is that voicing assimilation precedes metathesis. Bolozky rejects this interpretation on the general grounds that morphologically conditioned rules do not follow low-level phonetic rules. This conclusion is correct, and can be reinforced. Given the morphological restriction of the metathesis to the Hiptafel, and the existence of cognate infixes in related languages, the correct analysis is morphological infixation, as in (6b) above. As discussed above, the Guttural features spread from the stem-initial consonant onto the infixed position, resulting in
both voice and emphasis assimilation in TH. Since emphasis has been lost in MH, only the voicing assimilation is apparent.

Modern Hebrew now has what many observers have described as apparent surface exceptions to spirantization with surface [k]s that (generally) correspond to TH /q/, which, being emphatic, was systematically exempt from spirantization Bolozky (1978: 34) summarizes the situation:

(25) Historical /q/ has merged with /k/, and yet has remained totally unaffected by spirantization, as shown by such forms as: [kara] ‘thee read’ ~ [jikra] ‘will read’; [kana] ‘bought’ ~ [jikne] ‘will buy’; [dakar] ‘stabbéd’; [zarak] ‘threw’; and so on. This also makes spirantization opaque for many cases of phonetic [k] now occurring to which the rule does not apply.

As Bolozky points out, the existence of non-spirantizing [k] < TH /q/ increases the opacity of the grammar, as it introduces new instances of (10). There are two possible answers to this problem: preserve the historical distinction in the synchronic grammar, or differentiate between the two /k/s with some other feature. In the rule-based analysis, if we assume that MH retains underlying /q/, then there must be a rule that absolutely neutralizes /q/ to [k]. Clearly, this is a rule added subsequent to TH, and therefore we expect it to be added to the end of the grammar, and therefore for the rule to follow spirantization. This is exactly the behavior that is observed, and therefore this case would also confirm the rule-ordering theory of diachronic change. This is a plausible explanation for the change, but I have argued above that phonemic restructuring does take place, so what phonemic restructuring would be predicted in this case?

In MH the voiceless velars display a three-way contrast in behavior: one is always a spirant [x] (< TH /h/); one is always a stop [k] (< TH /q/); and one undergoes the stop/spirant alternation [k ~ x] (< TH /k/). This can be explained simply if we adopt a three-way distinction in the underlying representation of [cont], giving three distinct underlying segments: /x/ with [+cont], /k/ with [−cont], and /K/ without any specification for [cont]. As in TH, spirantization in MH is restricted to ‘filling in’ unspecified values for [cont], but it is further restricted by Structure Preservation to do so only if the output is an existing underlying segment.

Of course, the appearance of new phonemes /h/ and /v/ entails that they will be non-alternating and always [+cont]. But this analysis also makes the prediction that the ‘exceptional’ behavior of MH /k/ < TH /q/ should be able to lexically diffuse, and MH should gain non-alternating /p/ and /b/. This does seem to be happening, so that ‘[t]here are some borrowed verbs with initial b that is not spirantized in postvocalic position’ (Bolozky 1980: 6), for example:

(26) [bilef] ‘he lied, bluffed’
[mbealef] ‘he is lying, bluffing’
[jebalef] ‘he will lie, bluff’

The same can be observed to a more limited extent with /p/, for example
[pitpet] 'he talked a lot' [lepatpet] 'to talk a lot', (Bolozky 1978: 35). Ravid (1995: 82) gives further examples: [ibdu] 'lost PI', [mikroskop] 'microscope'. and [zlob] 'big, ungainly person'. These are obviously also additions to the language which are opaque under the definition in (10i). Notice that this results in cases which cannot be treated as lexical exceptions to spirantization at the level of the morpheme (the co-phonology approach; see also Inkelas et al. 1994; and Chapter 13 below), because within a single morpheme one segment can spirantize normally while another is 'exceptional', such as TH/pqh/ 'open eyes' MH [pakax] 'he opened eyes', [jihkax] 'he will open eyes'.

The opacities resulting from the neutralizations and phonemic restructuring observed in Modern Hebrew have another important effect—they render the memorization of URs ambiguous in some cases when the learner is provided with insufficient evidence from a paradigm. In Modern Hebrew there are two sources for [x], MH /x K/ (= TH /h k/) and two sources for [k], /k K/ (= TH /q k/). Thus, a learner when encountering a form with, for example, an initial [k] can propose either /k/ or /K/ in that position in the memorized form. Likewise, upon hearing [x] following a vowel the learner can propose either /x/ or /K/. These choices (quite possibly made with inadequate information) will then determine whether the newly memorized item will alternate or not in the learner's grammar; and mistakes (and uncertainties) of just this sort do occur, as documented in Bolozky (1980) and Ravid (1995) posing serious problems for Lexicon Optimization in OT.

Now let us consider how we might handle TH /q/ in MH using OT. First let us assume that we retain TH /q/ as MH /q/. Then we must obviously bar surface [q], perhaps through a general constraint against gutturals. Specifically, we would like to ban the surface manifestation of retracted tongue root, *[RTR]. But this is not sufficient, as we must also prevent /q/ from surfacing as [+cont] [x], while allowing /k/ to be [+cont] on the surface. The constraint will be substantially similar to (23), as shown in (27).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>q</td>
<td>Indifferent</td>
</tr>
<tr>
<td>[+ cont]</td>
<td>Surface</td>
</tr>
<tr>
<td>β ∈ α</td>
<td>Indifferent</td>
</tr>
</tbody>
</table>

However, (23) and (27) cannot be combined into a single constraint without also blocking spirantization of /k/, for the set of features shared by /q/ and /g/ also characterizes /k/.

The representational reanalysis into an underlying three-way distinction between /k/, /x/, and /K/ is more successful. Then all that is needed in OT is a highly ranked Ident([cont]) constraint, forcing input-output correspondent pairs to agree for the feature [cont]. However, the problem of /g/ remains. It would be possible, of course, to specify /g/ as [−cont] underlyingly and thereby ban it from spirantization. However, this analysis would then produce a strangely skewed underlying inventory, because there would be a [−cont] /g/ without a
minimally contrasting [+cont] */γ/ or an unspecified */G/. But by hypothesis underlying segments can be unspecified for [cont], and then it is odd that we must choose the more formally marked /g/ over the less marked /G/ as the sole voiced velar segment. Thus, as might be expected, OT forces us to take a less historical, more surface-orientated analysis of the behavior of TH /q/ in MH. The rule-based analysis can use this same analysis, or a historically orientated one.

The historical development of TH /q/, then does not particularly favor one theory or the other. However, the non-spirantization of /g/ along with the existence of a surface phone [ɣ] (from /x K/ through voicing assimilation) is difficult to handle in OT, but falls out directly in the rule-based Structure Preservation account. All of these changes also increase the opacity of the grammar by Kiparsky’s definitions, which is not the development favored by OT.

3.2.2 Degemination

As discussed above, surface geminates were immune from spirantization in TH, and the MH counterparts are still realized as stops, but they are no longer surface geminates, as Bolozky (1978: 34) explains:

(28) Gemination, which historically blocked Spirantization—as in dibber ‘spoke’, sipper ‘told’, makkar ‘acquaintance’, tabbax ‘(a) cook’, tappi ‘parasite’—is no longer manifested, but Spirantization is still invariably blocked where it used to exist—a circumstance which again renders the rule opaque.

As expected in the rule-based diachronic model, the addition of a general rule degeminating consonants, as in (29), is added to the end of the grammar, and thus follows the spirantization rule.

(29) \( x \rightarrow Æ / _ _ _ x \)
\[\text{Root}\]

This is exactly the analysis proposed in Chomsky (1951), with Spirantization (MR34) ordered prior to Degemination (MR44) Thus in rule-based terms there is a counterfeeding relation between spirantization and degemination, and this has increased the opacity of the grammar under clause (10i).

How will we handle this in OT? Obviously, we need a surface constraint against geminates. But, again, this is insufficient for the whole story. We must somehow prevent underlying geminates from surfaces as continuants. Again, following the general plan of (11) and (23), we can propose (30).

(30) *  
<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>x x</td>
<td>Indifferent</td>
</tr>
<tr>
<td>\ /</td>
<td>Indifferent</td>
</tr>
<tr>
<td>[− son]</td>
<td>Surface</td>
</tr>
<tr>
<td>[+ cont]</td>
<td>Indifferent</td>
</tr>
<tr>
<td>Relation β linked to α</td>
<td>Indifferent</td>
</tr>
</tbody>
</table>
That is, underlying geminates retain \([-\text{cont}]\) although they lose their bi-
 positional status through an analysis similar to the account of the failure of
 spirantization to affect /g/. The appropriate constraint ranking would be
 *Geminate \(\gg\) (30) \(\gg\) (11). Though underlying geminates must degeminate,
 it is still better for them to retain \([-\text{cont}]\), as shown in (31).

\[
\begin{array}{cccc}
\text{(31)} & \text{/dibber/} & \text{*Geminate} & \text{(30)} & \text{Spir} \\
\text{[dibber]} & *! & \checkmark & * \\
\text{[diber]} & \checkmark & \checkmark & * \\
\text{[diver]} & \checkmark & *! & \checkmark \\
\text{[diver]} & *! & \checkmark & \checkmark \\
\end{array}
\]

Notice that conceptually the OT account is already at a disadvantage. The rule-
based account had to make one new statement: the degemination rule. This
was added at the predicted place at the end of the grammar, and all other
effects immediately followed. The OT account, on the other hand, must not
only rerank the *Geminate constraint towards the top of the grammar but also
change the settings in (30) away from their default values of ‘surface’, which
were sufficient to characterize the constraint as it operated in TH. That is, the
most favored development under the OT account would be to simply rerank
*Geminate, and retain the unmarked values of ‘surface’ evaluation on (30).
This predicts the non-opaque pattern whereby historical geminates would
spirantize. But, in fact, MH is opaque in this respect. Thus, this development
is natural and expected under the rule-based theory, and unnatural and unex-
pected in the OT account.

There are two additional, empirical problems for the OT account. The first
problem with (30) is that derived geminates also block spirantization. One
process deriving geminates is /n/ deletion, (7j), illustrated in MH in (32):\(^3\)

\[
\begin{array}{ll}
\text{(32)} & \text{nava ‘he derived from’} \quad \text{jiba ‘he will derive from’} \\
\text{nafal ‘he fell’} & \text{jipol ‘he will fall’} \\
\text{nafax ‘he breathed his last’} & \text{jipax ‘he will breathe his last’} \\
\text{nifkad ‘he has been missing’} & \text{jipaked ‘he will be missing’} \\
\end{array}
\]

\((/j\text{a-n-paked/} \rightarrow j\text{appaked} \rightarrow [jipaked])\)

The /n/ deletion can most clearly be seen in the future of the Nif\'al binyan.
The [+cyclic] proclitic preposition /\text{min}#/ and the definite marker /\text{ha}#/ also

\(^3\) As Bolozky points out, the loss of /n/ and compensatory gemination is restricted to certain
(base) verbs. Thus while /n\text{b}V/ ‘derived from’ has future [jiv\text{a}V], /n\text{b}b/ ‘bark’ has future [jiv\text{b}ax].
The (derived) Nif\'al binyan verb forms regularly show loss of /n/ and no spirantization in the
future, though at the surface the stop immediately follows the future prefix vowel: jip\text{em} ‘he will
be moved’, jip\text{aer} ‘it will be opened up’, jip\text{ade} ‘he will be redeemed’, jip\text{ag}a ‘he will be hurt’,
jip\text{aked} ‘he will be missing’, jip\text{axed} ‘he will be frightened’, jip\text{ara} ‘it will be paid up’, jip\text{ared} ‘he
will separate’, jip\text{arek} ‘it will be unloaded’, jip\text{arem} ‘it was tipped’, jip\text{ares} ‘it will be spread out’,
jip\text{aret} ‘it will be changed’, jip\text{arec} ‘it will be broken into’, jip\text{asek} ‘it will be stopped’, jip\text{asel} ‘he
will be disqualified’, jik\text{ashel} ‘he will fail’, jib\text{ael} ‘he will have sexual intercourse’, jib\text{adek} ‘he will
be examined’, and numerous others.
caused gemination of the following consonant in TH, and MH has (as expected) the corresponding surface stops rather than fricatives. Since these geminate segments are derived rather than underlying, (30) is of no help in accounting for the non-spirantization. Rather, we would have to formulate a post-$n$ constraint as in (33).

\[
\begin{array}{ccc}
(33) & \text{Condition} & \text{Level} \\
\alpha & n & \text{Indifferent} \\
\beta & [-\text{son}, +\text{cont}] & \text{Surface} \\
\text{Linear Order} & \alpha > \beta & \text{Indifferent} \\
\text{Adjacency} & \text{Strict} & \text{Indifferent}
\end{array}
\]

However, (33) results in a constraint ranking paradox, as follows. For Niffl’al forms like /ja-n-paked/ → [jipaked], (33) must be ranked higher than (11), because (11) is violated at the surface in such forms. But for forms like /gan-mB-u/ → [ganvu] ‘they stole’, (11) must be ranked above (33) because (33) is violated at the surface in such forms. We can get around this problem for these two cases by setting the Adjacency evaluation parameter in (33) to ‘Underlying’, and ranking (33) >> (11). However, this will not suffice when we examine the imperfective verb cases. In rule-based terms, the cyclic application of vowel deletion feeds gemination in such forms: /ja-napol/ → janapol → jinpol → jippol → [jipol]. These forms are especially interesting because /n/ is not next to the /p/ at either the underlying or the surface level. In fact, /n/ is completely absent at the surface, so any effective modification of (33) must evaluate some aspect of underlying structure. Our only choice is then to modify the adjacency parameter to be ‘consonant to consonant’ (cf. McCarthy forthcoming: 15) But this then reinstates the problem for [ganvu].

The second empirical problem for the OT account is that TH did have a more restricted degemination rule which applied at the end of words, (7f), and fed spirantization, (3g). Some of these alternating forms survive in MH, such as /CVC,C/ nouns, as in (34), from Bolozy (1978: 38).

\[
\begin{array}{ccc}
(34) & \text{‘spoon’} & \text{kapot} & \text{‘spoons’} \\
\text{tov} & \text{‘drum’} & \text{tupim} & \text{‘drums’} \\
\text{rav} & \text{‘large’} & \text{rabim} & \text{‘large pl.’} \\
\text{dov} & \text{‘bear’} & \text{dubim} & \text{‘bears’}
\end{array}
\]

These examples fall out from the rule-based analysis with no further stipulations. Since the general degemination rule is added to the end of the grammar, it does not directly affect the specific degemination rule earlier in the grammar. Furthermore, the ordering of these two rules is consistent with the Elsewhere Condition, with the more specific rule applying before the more general rule (see also Halle and Idsardi, Chapter 10 above, for discussion of rule addition and the Elsewhere Condition). The specific rule was already ordered before spirantization In adding the general rule to the grammar, the Elsewhere
Condition requires that the new rule be ordered after the specific rule. In this particular case the new rule meets this condition by being ordered after spirantization. Therefore spirantization is sandwiched between two degemination rules, and these surface forms are correctly generated.

In contrast, this data is a problem for the OT analysis. The TH situation is not hard to handle. The TH version of (30) is evaluated at the surface, and the anti-geminate constraint is restricted to word-edges. But in MH the parameter settings have changed in (30) to partially 'Indifferent', and (30) must be ranked above (11). But this will also prevent spirantization of word-final degeminated stops, contrary to fact. Although alternations such as (34) are being lost in MH (Bolozy 1980), they are being levelled in only one direction, toward a spirant realization in all cases, indicating loss of the underlying geminates on a word-by-word basis. We do not observe the sudden levelling of (34) into stops, as would be predicted by (30). Therefore, we must rank another constraint in the grammar above (30), one possibility is (35), which (assuming the three-way underlying contrasts) will have to ranked below Ident[[cont]]

(35) * V [−son, −cont] prwd

Evidence for ranking (35) below Ident[[cont]] comes from words ending in /k/ < TH /q/.

Once again, the major development from TH to MH can be simply stated as an additional rule or a reranked constraint. What is different between the two cases is that placing the rule at the end of the generative grammar accounts for the rest of the facts without further stipulations, whereas in the OT account several additional constraints must be reranked or reparameterized in order to generate the correct forms. This is because the change to MH has increased the opacity of the grammar, with degemination creating new instance of (10i) type opacity.

3.2.3 Guttural loss

We have discussed already the change from TH /h/ to MH /x/. The other TH gutturals, /ʔ h ñ/, all show some effacements in MH, some of which is also observable in TH. Syllable-final /ʔ/ is deleted in TH, with a following stop being spirantized, (7c). In the very rare cases where /ʔ/ is maintained syllable-finally, it blocks spirantization, for example [waj的帮助下] ‘and surround 3ms impf.’ (Lev. 8: 7).

The other gutturals, /h ñ/, act variably in TH, either inducing post-guttural epenthesis or staying in syllable-final position. When in syllable-final position, they block spirantization of a following stop. Thus we have TH data such as in (36).
In MH [ʕ] has disappeared; /ʕ/ can show up as [ʔ] in prevocalic position, and is deleted elsewhere. The same distribution applies to /h/, which can surface as [h] prevocally, and is deleted elsewhere. This yields data in MH such as in (37), where the deleted segments /ʕ h/ are shown in parentheses.

This change also increases the opacity of the language, as these are additional instances of (10i).

The absolute neutralization of /ʕ/ to [ʔ] or [Ø] (the same distribution as /ʔ/)

has led some to propose that TH /ʔ/ /ʔ/ are merged into MH /ʔ/. Unfortunately, this account does not yield the correct spirantization facts, as loss of /ʔ/ still results in spirantization, [joxal] ‘will eat’ (Bolozy 1978: 18), whereas loss of /ʕ/ does not (36a-c). This also shows that we cannot handle /ʕ/ deletion as a feeding relationship between the rules /ʕ/ → /ʔ/ and /ʔ/-deletion. But since /ʕ/ → /ʔ/ is a new rule (not existing in TH), the prediction is that it will be added to the end of the grammar. This correctly accounts for the facts, and is also the analysis in Chomsky (1951), where Spirantization (MR34) precedes /ʕ/ → /ʔ/.
(MR42). Likewise, the general loss of /h ŋ/ is an innovation, and this rule, (38), should be added to the end of the grammar.

(38) \([-\text{cons}] \rightarrow \emptyset / _-\sigma\]

Guttural

This prediction is exactly borne out, with the general guttural deletion in syllable-final position following spirantization, but with the continuation of the TH /r/-deletion preceding spirantization, as it did in TH. Notice that this is the same effect observed with the two degemination rules. The more specific, historical rules are retained before spirantization while the general rules are added to the end of the grammar, following spirantization, and this ordering is in accordance with the Elsewhere Condition.

For the OT account, we will have to raise the ranking of the constraint barring /h ŋ/ from syllable-final position in the MH grammar because [h ŋ] are not observed in this position. But if this is the only reranking that we do, we will incorrectly predict that the now postvocalic stops will spirantize, contrary to fact. Thus, we also have to add a constraint preventing spirantization following underlying /h ŋ/, as in (39).

(39) *

\[\begin{array}{lll}
\alpha & \text{h / ŋ} & \text{Indifferent} \\
\beta & [-\text{son}, +\text{cont}] & \text{Surface} \\
\text{Linear Order} & \alpha > \beta & \text{Indifferent} \\
\text{Adjacency} & \text{C-to-C} & \text{Indifferent}
\end{array}\]

The problems with this account are similar to those encountered with (33) C-to-C adjacency is required to explain forms like /na-ʕakar/ \(\rightarrow\) [nekar], but it will then incorrectly block spirantization in post-guttural epenthesis cases, such as segolate nouns, for example /zaʕap/ \(\rightarrow\) [zâʔaf] 'rage, anger', but (39) incorrectly predicts *[zaʔap]. Put in surface-orientated terms, spirantization is only blocked by underlying /ʕ/ h/ when these segments themselves delete. (Even this statement is not completely accurate phonetically, as it is possible to elide /h ŋ/ quite generally.) But no formulation of that generalization is possible within the parameterized OT constraint theory. Finally, one additional problem with (38) is finding the feature combination which will pick out /h ŋ/ to the exclusion of /r/. Notice that defining this segment class was unnecessary in the rule-based theory because /r/-deletion applies first, allowing the added rule, (38), to be more general and delete all gutturals.

4. SUMMARY AND CONCLUSIONS

The examination of the role of spirantization in the grammar of Modern Hebrew shows that Modern Hebrew in fact has richer and more opaque
relationships among phonological processes than did Tiberian Hebrew. The innovations in Modern Hebrew do not give rise to decreased opacity as expected in OT (cf. also Koutsoudas et al. 1974 in this respect). Rather, the changes can be succinctly described only in a rule-based framework, where they are clustered at the end of the grammar. In contrast, the OT account of each of the developments examined here entails making extra changes in constraint parameters or rankings.

For example, the loss of geminates in MH and its attendant effects on spirantization should be simply storable in phonological theory. The rule-based theory adds a general degemination rule, (29), to the end of the grammar. Being at the end of the grammar, it is surface-true. The correct effects follow without making any other changes to the grammar. It is simple to bar geminates from phonetic forms in OT: simply put a constraint against surface geminates at the top of the grammar. Being undominated, it will be surface-true. But, unfortunately, if this is the only change we make, we will not generate the correct forms of MH. Instead, we must formulate and rank new constraints such as (30), (33), and (35) to generate the actual patterns of MH. Furthermore, there is nothing in the historical record to suggest that the hypothetical OT grammar obtained by simply making *Geminate undominated was an intermediate stage. In fact, it is clear that it could not have been an intermediate stage, as it would have completely neutralized the geminate/non-geminate distinction, which then could not have been reinstated. Therefore, it is evident for the cases we have considered here that the rule-based theory does a much better job of accounting for the diachronic changes.

In OT as developed in McCarthy (forthcoming), opacity is a fundamental concept, and OT grammars highly value transparent (surface-true) solutions. Since OT is specifically designed to disfavor opacity, the increase in opacity observed in the transition from Tiberian Hebrew to Modern Hebrew is unexpected and problematic for OT. In contrast, rule systems are not so easily characterized in terms of opacity, and in the present case the original hypothesis of Halle (1962) that new rules are added to the end of the grammar succinctly accounts for the interactions between various diachronic neutralizations and spirantization. Thus OT is not only wrong in the narrow technical sense that it cannot adequately handle cases like MH [jipol], but also wrong-headed as it is not yielding interesting questions or answers regarding the general principles of grammar and grammatical change.

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